Enhanced Visual Approach

The enhanced visual approach application is an extension of the current visual approach procedure. In this application, the CDTI is used by the flight crew to detect and track the preceding aircraft more effectively, thereby preventing numerous traffic call outs by ATC, allowing for the closure of large gaps between traffic, and reducing the number of go-arounds. The application is expected to improve the safety as well as the routine performance of visual approaches, and perhaps to reduce the weather conditions to which visual approaches can be conducted. The only operational changes from the current procedure are the use of flight identification during traffic call outs and the flight crew's use of the CDTI.

1.1 Introduction

Visual approaches are the backbone of operations at major airports in the United States. In their simplest form, visual approaches imply an approach to a runway visually, without following other traffic or the aid of electronic navigational guidance. However, when other traffic is present, visual approach conduct often includes the use of visual separation between aircraft. Either ATC or the flight crew may provide this separation, but often, the flight crew is responsible for maintaining separation between themselves and the aircraft they are following. In these instances, traffic advisories are issued to pilots (e.g., traffic, 1 o'clock, 4 miles, company 727), and once visual acquisition of traffic is confirmed, the flight crew is assigned responsibility for visual separation and a visual approach clearance is issued. The flight crew is then responsible for maintaining visual separation from the traffic they are following to their runway or to a closely spaced parallel runway.

The process of issuing traffic advisories and waiting for confirmation of visual acquisition is considerably more workload intensive for controllers than when visual approaches cannot be conducted; however, the increase in workload is accepted because of significant gains in runway capacity.

When visual approaches are conducted, the landing rate for a single runway is often higher. This is due to the fact that aircraft executing visual approaches typically land closer than in IMC (Weiss and Barrer, 1984). The most dramatic benefit of being able to conduct visual approaches is in multiple runway operations. When visual approaches are conducted, most busy U.S. airports utilize two or more independent arrival streams to their runways.

1.1.1 Background

When conditions become marginal, controllers may need to issue traffic call outs to the flight crew repeatedly until they report traffic in sight. The controllers may also have to query the flight crew as to whether they have acquired their traffic visually. At some point, this communication workload may become high enough and unmanageable enough that visual approach operations are suspended.

When visual approaches cannot be conducted, one or more approach streams may be suspended depending on the runway geometry, resulting in a significant loss of airport capacity (Mundra and Buck, 1990; Mundra, Cieplak, Domino, and Peppard, 1993). Once visual approaches are suspended, a reduction in capacity generally occurs. For example, BOS and SFO experience a reduction in capacity of approximately 40% to 50% when visual approaches cannot be conducted and a single runway must be used. Dallas-Fort Worth (DFW) and Atlanta (ATL) airports experience a reduction of approximately 16% in capacity when they are no longer able to conduct visual approaches but must conduct simultaneous ILS approaches.

Figure 1 and Figure 2 show two geometries controllers may use during approaches in marginal conditions to provide a longer time for the flight crew to acquire the traffic visually. Both geometries are very labor intensive. In Figure 1, as aircraft continue to approach the runway, the eventual approach to the runway becomes more and more difficult for the flight crew. AC 2 may have to be broken out and eventually the visual operation may have to be suspended.

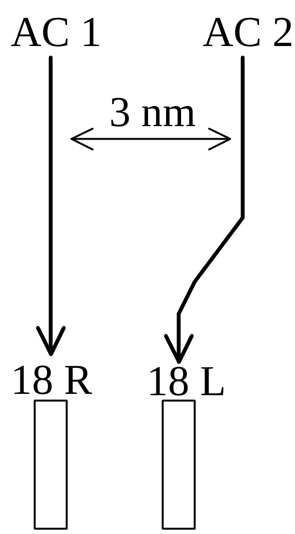

Figure 1. Plan view of an approach course for visual approach

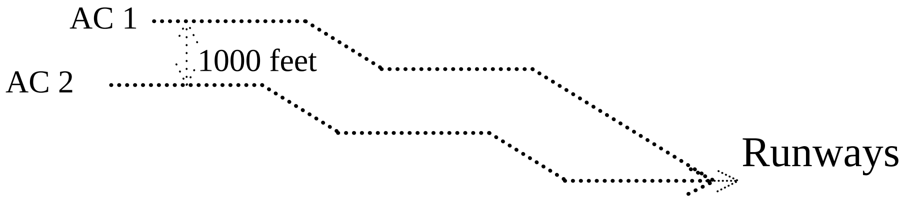

Figure 2. Profile view of two parallel approach courses for visual approaches to parallel runways

The geometry shown in Figure 2 is especially workload intensive in that "step-downs" while maintaining 1000 foot vertical separations are workload intensive. Since the relative positions of the aircraft may change, the controller may be required to issue traffic call-outs with each step-down. Environmental restrictions may require such step-downs to begin at fairly long distances on final. These instructions are of high priority since they are meant for aircraft on final approach. This reduces the time the controller can devote to the rest of the traffic pattern, such as turns to base or final. Eventually, as the operation becomes highly workload intensive, the controller may be forced to suspend the visual operation.

Visual approaches can be difficult for the flight crew also. In his analysis of visual approach operations, Stassen (1998) examined the Aviation Safety Reporting System (ASRS) database for reports relating to visual approaches from the years 1992 through 1995. Results from this search revealed 150 reports where pilots noted that the safety of the flight was compromised during their conduct of the visual approach. Stassen (1998) provides a summary of these reports and identifies several instances where the CDTI could have enhanced the safety of these operations.

During visual approach procedures, the flight crew may have difficulty visually identifying aircraft, and may even identify the wrong aircraft as the traffic of concern. As explained above, the visual acquisition task is especially critical during the visual approach, as it requires an unambiguous identification of a particular aircraft from which the pilot will be required to maintain visual separation.

When conducting visual approaches to parallel runways, the flight crew may receive instructions to visually acquire traffic inbound to the parallel runway, knowing that after turn on, they may be next to each other. In such a situation, it is often difficult for the flight crew to judge the relative geometry visually, making it difficult to determine a proper intercept angle to ensure an adequate spatial relationship with the target (e.g., stay slightly behind traffic after turn-on to final approach).

Once established on final, pilots may find it difficult if not impossible to adhere to a visual approach clearance. This is because pilots rely primarily on visual cues to recognize the speed changes of preceding aircraft. As a result, the flight crew is sometimes surprised by unexpected slow-downs of the proceeding or adjacent aircraft, requiring them to rapidly adjust speed, reconfigure the aircraft, and in some cases request a breakout. A breakout may also occur when the flight crew looses sight of the preceding aircraft due to low visibility or having the sun low to the horizon making it difficult to see.

1.1.2 Operational purpose

The information depicted on the CDTI is intended to provide assistance with several components (listed below) of the visual approach procedure.

• **Improve visual acquisition of traffic**. Flight tests have shown that the average traffic acquisition time with the aid of a traffic advisory combined with a traffic display is considerably more effective than an unalerted search (Andrews, 1984, 1989, & 1991). Olmos, et. al., (1998) has shown that this time is further reduced in complex traffic conditions when aircraft identification is available on the display. Faster acquisition of traffic by pilots will reduce the time between issuance of advisories and confirmation of traffic acquisition and may result in reduced controller and pilot workload. Finally, faster traffic acquisition may enable the reduction of the 500-foot buffer above MVA for the conduct of visual approaches.

• **Aid positive identification**. The demands of the visual search environment can lead a pilot to misidentify an aircraft of concern. Use of and the display of flight identification will help to establish a specific traffic on the display as the target of interest and further will aid in the positive identification of the associated airplane visible out the window.

• **Reduce the probability of loss of visual operation.** The CDTI can provide a capability to highlight or identify the traffic on the display that may help maintain cognizance of that traffic during high workload terminal operations. This will be especially true in simultaneous parallel runway operations, or any other time that numerous traffic is depicted on the display. This capability would also help support the continuous correlation of the visual target to the displayed target.

• **Aid judgments of range, closure, and encounter geometries**. The CDTI can provide range and speed or closure information of a selected target that will help pilots confirm the selection of appropriate speeds on final. This allows for better monitoring of range and potentially the closing of large spacing intervals between aircraft. It may also reduce the incidence of surprise due to unexpected slowdowns by the traffic to follow, by enhancing the pilot's awareness of speed differences before the decreases in range are apparent using visual cues alone or by scanning targets without speed information (e.g., TCAS). The information available on the CDTI will facilitate faster recognition of slowdowns and is therefore, expected to reduce the number of go-arounds.

Providing ground track information may increase the pilot's traffic awareness by providing the necessary cues to judge aircraft positioning (e.g., downwind, base, or final). During merges onto final, this information may also augment pilot judgments of closure geometries when the pilot is required to space own aircraft properly during a merging operation.

• **Reduce controller workload in marginal VMC**. When conditions are less than ideal for visual acquisition and controllers have to revert to geometries such as those depicted in Figure 1 and Figure 2, CDTI information may reduce controller workload. It may reduce workload since controllers will not need to provide repeated call outs for the same traffic due to faster acquisition times by the flight crew. This may enable controllers to conduct visual approaches to lower minima.

1.1.3 Domain

Enhanced visual approaches via a CDTI will occur during the approach phase of flight in all types of airspace under visual meteorological conditions (VMC) or marginal VMC. It will also be applicable to both radar and non-radar environments. Many different aircraft with different equipage and speeds will be operating within this environment.

1.1.4 Justification

This procedure is expected to provide an increment in safety through improved situational awareness and in capacity through reduction in workload of the controller (see Olmos, et. al., 1998). Additionally, the CDTI could allow for a reduction in the current minima for visual approaches of minimum vectoring altitude (MVA) plus 500 feet. This 500-foot buffer could be reduced if aircraft are able to acquire traffic more quickly with a CDTI. Lowering the weather minima in which visual approach operations can be conducted will mean reduced delays and greater schedule reliability. This is expected to provide specific monetary benefits to operators (see Mundra, et. al., 1998).

Other possible benefits listed in section 1.1.2 include the reduction of spacing between aircraft on final, reduction in the number of go-arounds during visual approaches, as well as improved acquisition, identification, and tracking of traffic.

1.1.5 Maturity and user interest

This application is mature (see Stassen, 1998 and Olmos, et. al., 1998). The CDTI is expected to be an enhancement to the current procedure with minor procedural changes. A cargo airline association evaluated this procedure in operational flight evaluations in 1999 as part of the Safe Flight 21 program’s operational goals for FY2000.

1.2 Operational concept, roles, and procedures

1.2.1 Concept description

When conducting the CDTI enhanced visual approach procedure, the flight crew would fly the visual approach as is done currently but they would have additional electronic information available on the CDTI to aid in their conduct of the approach. This additional information will allow the flight crew to determine target position, spacing, flight identification, closure rate or ground speed, and ground track. The additional information available in the cockpit allows the controller to use aircraft identification during traffic callouts, thereby reducing verbiage.

1.2.2 Procedures and responsibilities

1.2.2.1 Air traffic control

Controller procedures and responsibilities are not expected to change significantly with the use of a CDTI for enhanced visual approaches. However, since flight identification is added as an enhancement to the CDTI, controllers will issue flight identification when informing a pilot of an aircraft. Using flight identification may reduce ATC workload since they may not be required to issue repeated traffic advisories and/or to include range, bearing, and altitude information.

During a mixed equipage environment, pairing aircraft that are appropriately equipped may be challenging for ATC. However, if their workload is lower on the final approach course due to fewer callouts, controllers may have sufficient abilities to pair the aircraft that are appropriately equipped. If TIS-B were available, traffic information could be broadcast to all CDTI equipped aircraft. With TIS-B, the ADS-B equipage and its associated pairing issues would not be a concern and may increase the acceptability of the procedure.

1.2.2.2 Flight crew

Pilot responsibilities with regard to ATC will not change; however, cockpit procedures will now include the pilots' use of a CDTI to acquire and maintain cognizance of the aircraft position and distance with a visual scan outside the cockpit and the CDTI. Pilots can monitor the other aircraft's parameters on the CDTI so that they are able to monitor trends and space own ship appropriately.

Pilots would need to interact with the CDTI to choose functions such as target selection. Such interactions should be examined to determine whether they interfere with other duties and the pacing of flight crew tasks required in the terminal environment.

1.2.3 Proposed new phraseology

Communications will involve the use of flight identification. For example, with a CDTI, the traffic advisory could be: "XYZ 123, traffic is ABC 456 at twelve o'clock. Report in sight." instead of the current, "XYZ 123, traffic twelve o'clock. 3 miles. Company 737. Report in sight." For a detailed example, see section 1.2.5.

1.2.4 Aircraft separation minima

There is no effect on aircraft separation minima.

1.2.5 Sample scenarios

<u>Scenario 1:</u> Typical approach (Illustrative of the enhancement of the routine conduct of visual approaches)

A typical exchange with flight identification could be the following: AC 2 is on base at Boston and is told by the final controller, "{AC2 ID}, traffic is {AC1 ID} at twelve o'clock. Report traffic in sight." The flight crew of AC 2 turns on the flight identification function and notes the relative angular position of two other aircraft with respect to AC 1 and then visually identifies AC 1 out the window from the two other potential targets. AC 2 then replies, "Boston approach, {AC2 ID}, {AC1 ID} in sight." Boston TRACON then clears AC 2 for the approach, "{AC2 ID} maintain visual separation with {AC1 ID}. Cleared for visual approach runway 15R. Contact tower on 128.8." The flight crew confirms this clearance, selects AC 1 on the CDTI; monitors the CDTI for the range and speed of AC 1; and flies the approach visually while keeping the preceding aircraft in sight through out-the-window visual scanning.

Scenario 2 (a) & (b): Slowdown scenarios (Illustrative of the enhancement of the safety of visual approaches)

(a) To the same runway: The initial clearance is issued as in scenario 1. While AC 2 is following AC 1, AC 1 slows down to a much slower speed inside the outer marker; so much that if AC 2 had continued on its plan, AC 1 would not have cleared the runway before AC 2 crosses the threshold. AC 2 or the tower would have recognized this later in the approach and AC 2 would have executed a breakout maneuver. However, with the ground speed cue available on the CDTI, AC 2 detects the early slowdown, and reduces its speed in time to be able to maintain adequate spacing to the runway, preventing the need for executing a go-around.

(b) Closely spaced parallel runways (runway centerlines closer than 2500 feet): AC 3 may be cleared to followed and not pass AC 4, which is cleared to a closely spaced parallel runway. AC 4 may slow down early such that AC 3 may eventually overtake it, and pass it, thus losing visual contact. The presentation of the speed cue for the traffic may enable AC 3 to adjust its own slowdown somewhat so as not to overtake AC 4.

Scenario 3: Visual approach to parallel runways (Illustrative of the enhancement in capacity or efficiency of visual approaches)

Visual approaches are being conducted to runways 16L and 16R at Seattle Tacoma International Airport. Conditions are 4000 feet and 6 miles visibility. Aircraft to each runway are no longer able to see each other on long final or base turning final. The final controller therefore sets up the two streams of traffic to the two runways. Two conditions will be discussed: one without a CDTI and one with a CDTI.

Without the CDTI. AC 1 is at 8000 feet for 16L and AC 2 is at 7000 feet for 16R (see Figure 2). AC 1 is issued the clearance, "{AC1 ID}, traffic 2 o'clock. Company 727. Report in sight." AC 1 replies, "Traffic not in sight." As the aircraft proceed toward the runways, each aircraft is cleared to a lower altitude in turn, with the lower aircraft being first. There is a slight speed differential between the two aircraft, and AC 2 is now at 1 o'clock with respect to AC 1. AC 1 is now at 7000 feet, and AC 2 is at 6000 feet. AC 1 is again given the instruction, "{AC1 ID}, Traffic 1 o'clock. Company 727. Report in sight." AC 1 again replies, "Traffic not in sight." This continues until both aircraft are at some altitude below 4000 feet when AC 1 can visually acquire AC 2 and advise ATC. ATC can then clear AC 1 for a visual approach.

This procedure required 4 or 5 instructions to AC 1. If the traffic is heavy enough, the controller may not be able to devote this much time and effort to one pair of aircraft and may have to decide to suspend the visual approach operation even though the ceiling is 4000 feet.

With the CDTI. Upon the initial turn on to final, AC 1 is at 8000 feet and AC 2 is at 7000 feet on long final. AC 1 is issued the instruction, "{AC1 ID}, traffic is {AC2 ID} at one o'clock. Report in sight." AC 1 confirms, "{AC1 ID} has {AC2 ID} on CDTI. Will report in sight." At 4000 feet, AC 1 breaks through the ceiling and reports AC 2 in sight. ATC now clears AC 1 to visual approach to runway 16L.

In this scenario, ATC still provides the same number of instructions to both aircraft for altitude changes, however, it issues only one instruction for visual acquisition. This may make enough of a difference that even under heavy traffic conditions, the controller may not need to suspend the visual approach operations at 4000 foot ceilings, thus enabling visual approaches to a lower ceiling.

The workload of descending both aircraft with altitude instructions 1000 feet at a time is still workload intensive due to the fact that it requires surveillance actions and various mental activities in addition to communications. It must be determined through simulations and operational experience as to the extent of the CDTI benefit in enabling approaches to lower minima.

<u>Scenario 4</u>: Closure of spacing on the final approach by the trail aircraft (Illustrative of the ability of the trail aircraft to tighten spacing on final approach)

This scenario starts with both aircraft established on long finals for visual approaches to runway 22 at night. AC 1 will behind AC 2.

At this point, the AC 1 flight crew has already selected AC 2 on the CDTI. The flight crew of AC 1 monitors the CDTI and notices that AC 2 is at a range of 6 miles and has a 10-knot slower ground speed (this judgement is very difficult for the flight crew to perform while looking at the target out the window). While keeping AC 2 visually in-sight, the flight crew of AC 1 determines that they can comfortably maintain their 10-knot differential in ground speed and close up the 6-mile gap without overtaking or encroaching too closely on AC 2.

1.3 Requirements

1.3.1 CDTI capabilities

Olmos, et. al. (1998) conducted a study that explored the potential utility of various CDTI features for enhanced visual approaches. This evaluation determined that target flight identification, target speed cue, and target selection were crucial features for enhanced visual approaches. Some question did exist though as to the utility of the ground track vector[1]. The evaluation also determined that no alerts were necessary for this procedure. A potentially useful feature is traffic category, which could provide the flight crew information on an aircraft's broad category and / or size (see RTCA, 1998b).

[1] This data was not conclusive. However, subsequent simulations and an operational evaluation have used ground track vectors and found them to be worthwhile. Nevertheless, pilots have expressed concern about display clutter. The *possibility* exists that the *CDTI may be required to provide* the ability to turn *off* the ground track vectors and thus declutter the display. Further examination may be necessary to determine if this feature is a requirement.

Table 1. CDTI features for enhanced visual approaches (RTCA, 1998a)

Feature	Need
Own aircraft symbol	**Required**
Traffic symbol	**Required**
Traffic relative altitude *	**Required**
Traffic pressure altitude *	Optional
Traffic relative bearing	**Required**
Traffic range	**Required**
Traffic identification	**Required**
Traffic vertical rate	Optional
Traffic horizontal velocity vector	**Required**
Traffic category	Optional
Alert	Optional #
Selected target closure rate	**Required****
Selected target aircraft ground speed	**Required****
Target selection	**Required**
Target highlighting	**Required**
Extended display range (90 nm)	-
Range reference	**Required**

* Either pressure altitude or relative altitude has to be displayed but both are not required to be displayed

** Either closure rate or ground speed, but not both, are required

If the pilot is unable to include the CDTI as part of the normal instrument scan, an alert may be required to inform the pilot of the desire to view the CDTI or need to look out the window. Alerting may also be a necessary safety enhancement for certain operations. The alerting criteria and form of alerting, if any, are to be determined.

Data accuracy requirements for this procedure will be more stringent than for the enhanced visual acquisition (see Table 1). The requirements must allow the flight crew to not only visually acquire but to discriminate between numerous aircraft in a densely populated terminal area.

1.3.2 Infrastructure requirements

1.3.2.1 Aircraft

The equipment needed on the aircraft will include the CDTI and the associated processing systems.

1.3.2.2 Ground ATC

Depending on the input source to the CDTI, some ground infrastructure may be required. A CDTI that relies upon ADS-B will not require any ground infrastructure for this application; however, one that relies upon TIS-B information will require ground stations for the uplink of traffic information. ATC will need to have knowledge of the aircraft equipage level, e.g., ADS-B transmit only, CDTI with ADS-B information, CDTI with TIS-B only. Such information could be revealed, in the near term, in the aircraft flight plan or could be manually entered locally in the flight data block. In the long term, the aircraft's equipage level should be conveniently available without extra effort, whenever that information is required.

1.3.3 Training requirements

Flight crews will need to be trained on the use of CDTI equipment for enhanced visual approaches. A few issues that must be addressed in training include over-reliance on the equipment to the detriment of an out-the-window scan, head-down time, and a mixed equipage environment. Air traffic controllers will have to be trained on the use of aircraft call sign / flight identification.

1.4 Other issues

1.4.1 Relationships to other programs

The Safe Flight 21 program is considering use of enhanced visual approach procedures as a key component of its program. A cargo airline association demonstrated this procedure in a flight evaluation in July of 1999.

1.4.2 Other considerations

<u>Use of flight identification</u>: Currently, flight identification is not used by ATC. The benefits from this application rely, on part, on the use of flight identification by the flight crew and ATC. The air traffic control handbook (FAA Order 7110.65) would have to be modified to allow for the reduction in the current phraseology. The use of flight identification for traffic callouts as an addition to current communications is neither currently allowed or prohibited. Therefore, a change to FAA Order 7110.65 may be necessary to clarify and allow for the use of flight identification.

<u>Identification of equipped aircraft</u>: Controllers must have a mechanism to identify CDTI equipped aircraft capable of conducting this procedure. Although this could be done through an identifier in the data block, it is doubtful that an identifier could be implemented in the current automated radar terminal systems (ARTS). An alternative would be to accomplish this procedurally, with equipped aircraft announcing to controllers that they are

capable of CDTI enhanced visual approaches. Eventually, CDTI equipage should be displayable so that the information is quickly and easily perceived while a controller scans traffic.

Equipage: Initially all aircraft will not be CDTI equipped. The concept must be useable to controllers in a mixed CDTI equipage environment. It may be useable for limited CDTI equipage as long as those who are CDTI equipped can display relevant information for all traffic whether CDTI equipped or not. ATC will need to have knowledge of the aircraft equipage level, e.g., ADS-B transmit only, CDTI with ADS-B information, CDTI with TIS-B only. The implementation of this application will likely be problematic if controllers are required to determine who is equipped and who is not and issue instructions only when an equipped pair appears. This would also be true if controllers have to deliberately pair CDTI aircraft. Evaluations may be able to answer some of these questions. Availability of TIS-B may mitigate these issues.

Flight crew issues: The issues of flight crew workload, situational awareness, training, and procedures must also be considered. Flight crew workload in the terminal environment is already high. The addition of the CDTI on the flight deck may increase flight crew workload due to the fact that they have one more item to interact with while also attending to other cockpit duties. However, it will reduce the uncertainty and possibly the workload in acquiring an aircraft, and may also reduce their workload in maintaining visual contact once an aircraft has been identified. It will also increase their traffic awareness, which could reduce mental workload.

Worldwide applicability: Very few foreign states use visual separation as a means of separation in visual approaches. Limited use may exist in Canada, Netherlands, and Germany.

1.5 Summary

A CDTI enables enhancements to the routine operation of visual approaches as well as to the safety of visual approaches through features that provide greater situational awareness with respect to traffic of concern. A CDTI may also enable the continuation of visual approaches to closely spaced parallel runways to minima lower than currently experienced due to a potential reduction in controller workload combined with augmented flight crew surveillance awareness that compensates for reduced VFR visibility. Other benefits include the reduction of spacing between aircraft on final, reduction in the number of go-arounds during visual approaches, as well as improved acquisition, identification, and tracking of traffic.

1.6 References

Andrews, J. W. (1984). *Air-to-Air Visual Acquisition Performance with TCAS II*, Project Report ATC-130, DOT/FAA/PM-84/17, Massachusetts Institute of Technology Lincoln Laboratory, Lexington, MA.

Andrews, J. W. (1989). “Modeling of air to air visual acquisition,” *The Lincoln Laboratory Journal*, Vol. 2 #3, Massachusetts Institute of Technology Lincoln Laboratory, Lexington, MA.

Andrews, J. W. (1991). *Unalerted Air-to-Air Visual Acquisition*, Project Report ATC-152, DOT/FAA/PM-87/34, Massachusetts Institute of Technology Lincoln Laboratory, Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, MA.

FAA (1997). *Air Traffic Control Handbook, Order 7110.65J, Department of Transportation,* Department of Transportation Federal Aviation Administration, Washington, DC.

Mundra, A. D., and Buck, W. W. (1990). "The Need for Multiple VFR Approach Concepts," *The Journal of Air Traffic Control.* January-March, Arlington, VA.

Mundra, A. D., Cieplak, J. J., Domino, D. D. , and Peppard K. (1993). "Enhancing Visual Approaches with the TCAS Traffic Display," *Proceedings of the Air Traffic Control Association Annual Meeting*, Fall 1993, Nashville, TN.

Mundra, A. D., Cieplak, J. J., Domino, D. D. , Olmos, B. O., Stassen, H. P. (1998). *Potential ADS-B/CDTI Capabilities for Near-Term Deployment*. MITRE Paper MP 98W0000004, The MITRE Corporation Center for Advanced Aviation System Development, McLean, VA.

Olmos, B. O., Mundra, A. D., Cieplak, J. J., Domino, D. A., and Stassen, H. P. (1998). *Evaluation of near-term Applications for ADS-B/CDTI Implementation. Proceedings of SAE/AIAA World Aviation Congress, Society for Automotive Engineers, Inc,* Warrendale, PA.

RTCA (1998a). *Guidance for Initial Implementation of Cockpit Display of Traffic Information*, Document No. RTCA/DO-243, Washington, DC.

RTCA (1998b). *Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B),* Document No. RTCA/DO-242, Washington, DC.

Stassen, H. P. (1998). *Enhancing the Safety and Efficiency of Runway Approaches Using a Cockpit Display of Traffic Information,* MITRE Working Note WN98W0000005 , The MITRE Corporation Center for Advanced Aviation System Development, McLean VA.

Weiss, W. E., and Barrer, J. N. (1984). *Analysis of Runway Occupancy Time and Separation Data Collected at La Guardia, Boston, and Newark Airports,* MITRE Paper MTR-84W228, The MITRE Corporation Center for Advanced Aviation System Development, McLean VA.